Analysis and Acquisition of Observations of the Circulation
on the California Continental Shelf

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Day Three: Biology/Physical Oceanography

Whales, Krill, and Variability of Two Coastal Upwelling Centers

Scott Benson

The world's most productive fisheries and marine bird and mammal foraging areas are located in coastal upwelling centers. Temporal variability in strength of upwelling can affect primary production, zooplankton productivity, and the distribution and abundance of fish and marine birds and mammals. Unfortunately, our understanding of the link between large-scale oceanographic changes and variability of coastal margin upwelling is limited. In particular, the potential biological affects of global climate change on upwelling-dependent ecosystems cannot be assessed due to a lack of information on the linkage between physical changes, primary production, and higher trophic level consumers. For the past 4 years we have been studying the impacts of El Niño and La Niña events on coastal upwelling, primary production, zooplankton production and the distribution and abundance of marine mammals and sea-birds in the Monterey Bay, California upwelling system of the California Current.

We propose to expand our current research efforts to examine the relationship between foraging ecology of marine birds and mammals and coastal upwelling dynamics along the California coast. Our study area will expand to include both the Monterey Bay and Channel Islands upwelling centers (Figure 1). Because these centers are distant from each other, we suspect upwelling pulses may be temporally discoupled.

Our studies in Monterey Bay have confirmed that euphausiids, or krill, have the highest biomass of all zooplankton grazers in the Monterey Bay upwelling system. Krill form a key trophic link in coastal upwelling systems between primary production and higher trophic level consumers. Most species (including humans) are only one or two trophic levels away from krill, it is the primary prey of 7 of the 10 most important nearshore commercial fishes on the central California coast, and it generally makes up over 90% of the diet of endangered blue and fin whales. Ultimately, the fate of planktivorous predators depends upon reliably available concentrations of krill in coastal upwelling centers.

While our studies have shown the importance of the Monterey Bay National Marine Sanctuary upwelling center, they have also underlined the importance of other upwelling centers. Data we collected during the 1997/98 El Niño and 1999 La Niña events in the Monterey Bay upwelling system demonstrate the close link between upwelling and rorqual whale abundance. In July 1997, krill abundance declined sharply in response to El Niño warming of nearshore waters (Figure 2). Paradoxically, this led to a dramatic increase in large whale abundance (Figure 3). The explanation lies in what was happening offshore and in other upwelling centers. While productivity was low in Monterey Bay during the 1997/98 El Niño, it was even further reduced in other foraging areas. Thus, the limited amount of productivity in Monterey Bay was the best foraging area available for the whales. Conversely,

by May 1999, the strongest La Niña event on record brought cold nutrient-rich waters into Monterey Bay, supporting high primary production and the greatest krill abundances recorded during our 4-year study. However, by July 1999, krill abundance decreased sharply (Figure 2) and whale densities declined (Figure 3). We believe the whales moved to different foraging areas, including the Santa Barbara Channel, where conditions were better. Unlike our observations in Monterey Bay, upwelling off the Channel Islands appeared to persist strongly throughout the summer and early fall, with dense aggregations of krill reported by whale-watching vessels throughout the summer months. This demonstrates the importance of productivity across upwelling centers as well as within.

Long-term survival of many eastern Pacific marine bird and mammal populations depends upon the summer/fall productivity of upwelling centers off the U.S. West coast , including Monterey Bay, Gulf of the Farallones, Cordell Bank, and Point Conception. Satellite information has demonstrated that these different upwelling systems have distinctly different periods of productivity. To establish similarities and differences between California upwelling centers and their consequences, we propose to address the following specific questions in both the Monterey Bay and Channel Islands National Marine Sanctuaries:

How are spatio-temporal patterns in the distribution and abundance patterns of krill linked to spatio-temporal patterns in coastal upwelling? Are these linkages established through impacts on krill larval production, recruitment to adult populations, or growth of adult populations?

- Does variability in water temperature or food availability affect the growth of individual euphausiids?
- How are the two upwelling areas similar and different in the distribution, density and timing off productivity?
- How do highly mobile predators respond to these differences?

Using the answers to these questions we will develop:

Dynamic state mathematical models for krill life histories to examine different scenarios of the effects of climate induced changes in upwelling on:

- krill population dynamics,
- prey availability to planktivorous predators, and
- the consequences of climate-induced changes in upwelling patterns on marine birds and mammals feeding in coastal upwelling regions.

Recognizing the importance of this information to management, both the Monterey Bay (MBNMS) and Channel Islands National Marine Sanctuaries (CINMS) have pledged research vessel support. MBNMS has requested support for our surveys from the National Marine Sanctuaries head office. CINMS has pledged the use of their research vessel, R/V Ballena for our work.

Study Design

Monthly surveys will be conducted during May - November 2000 within the Monterey Bay and Channel Islands study areas. A set of transect lines, spaced at an interval of 5.5 km, will be chosen randomly for survey at a constant speed of ten knots during two consecutive days (Figure 1). While the ship is underway, observers will search for marine mammals and sea-birds with a pair of 7x25 power FUJINON binoculars fitted with reticle markings and a compass. Zooplankton backscatter will be assessed with a SIMRAD EY500 echosounder, transmitting a 200 kHz signal at an interval of two seconds, and integrated to a maximum depth of 200m. Net tows will be conducted for identification of zooplankton backscatter. Hydrographic sampling will be conducted to assess sea surface temperature and thermocline depth with a SEABIRD 19 vertical profiler. Surface water samples will be collected at hydrographic stations for chlorophyll analysis.

Relevance of the Santa Barbara Channel (SBC)/Santa Maria Basin (SMB) Circulation Study: In the Monterey Bay area, the data gathered by the Monterey Bay Aquarium Research Institute have proven invaluable for understanding the physical processes both within our study area and farther offshore. It is our hope that the data obtained and made available by the Center for Coastal Studies will be similarly useful to our studies in the Santa Barbara Channel area. In particular, temperature profiles, satellite images (when available), and drifter tracks are likely to be insightful when interpreting patterns of krill and whale abundance in this area. Recent ADCP data on MBARI moorings have also provided independent measures of zooplankton abundances throughout the water column and at a finer temporal resolution. If it were possible to add such data collecting/processing capabilities to the ongoing SBC/SMB studies, this would be beneficial to our study. Passive hydrophones could also provide a means of measuring the relative abundance of whales in the area, and we would be very interested in discussing the possibility of adding such instrumentation.

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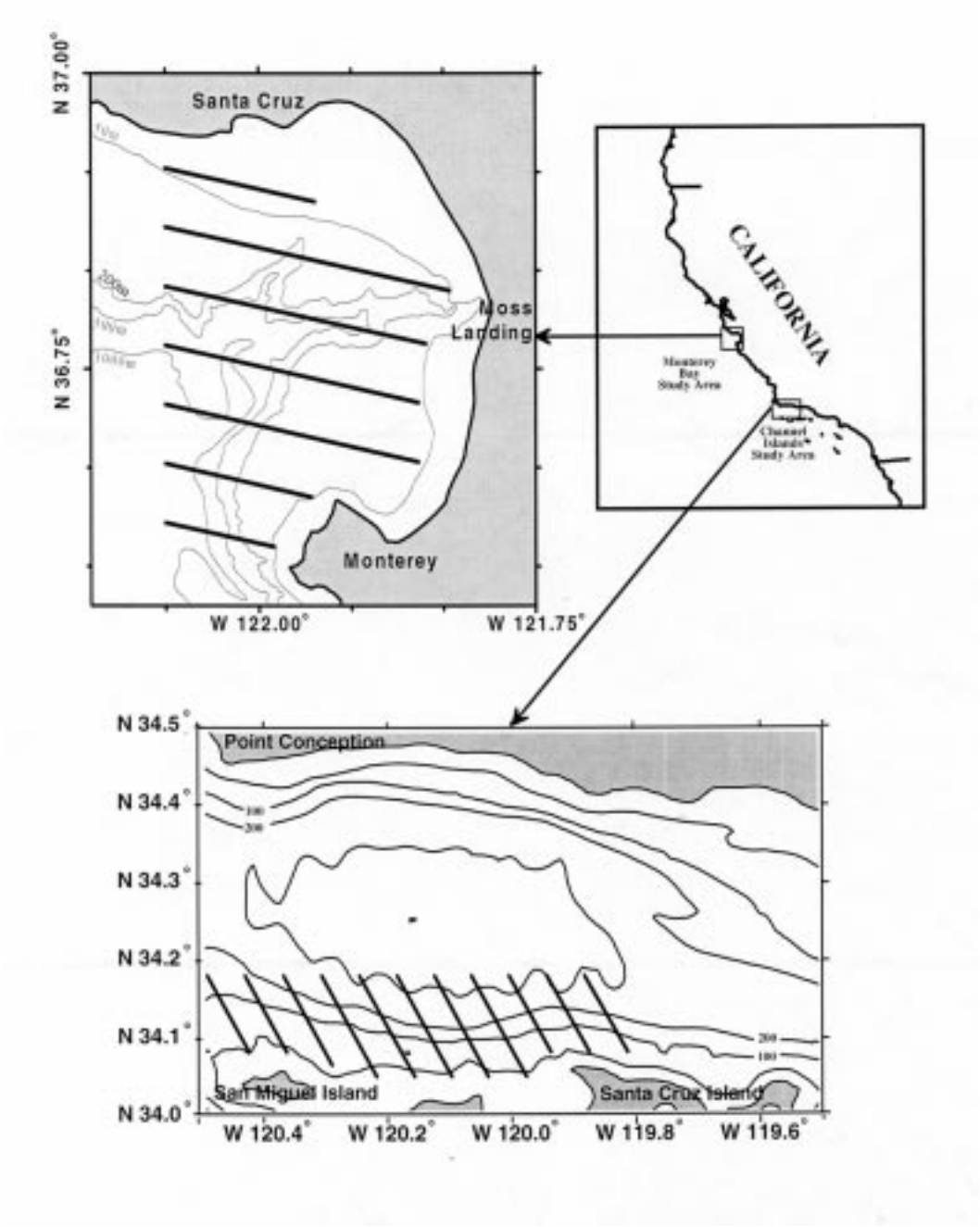

Figure 1: Study areas in Monterey Bay (top) and Santa Barbara Channel (bottom), with sets of representative transect lines. Depth contours in meters.

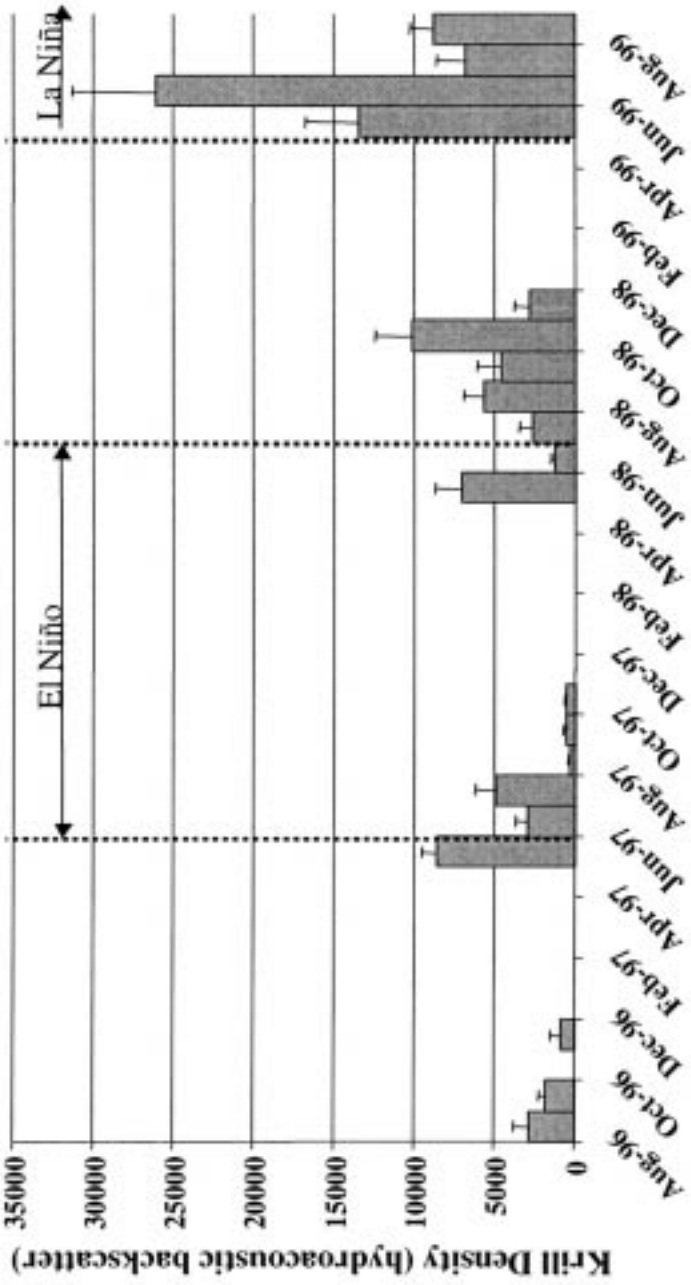

Figure 2: Krill density (surface area backscatter) in Monterey Bay, California. Error bars indicate one standard error.

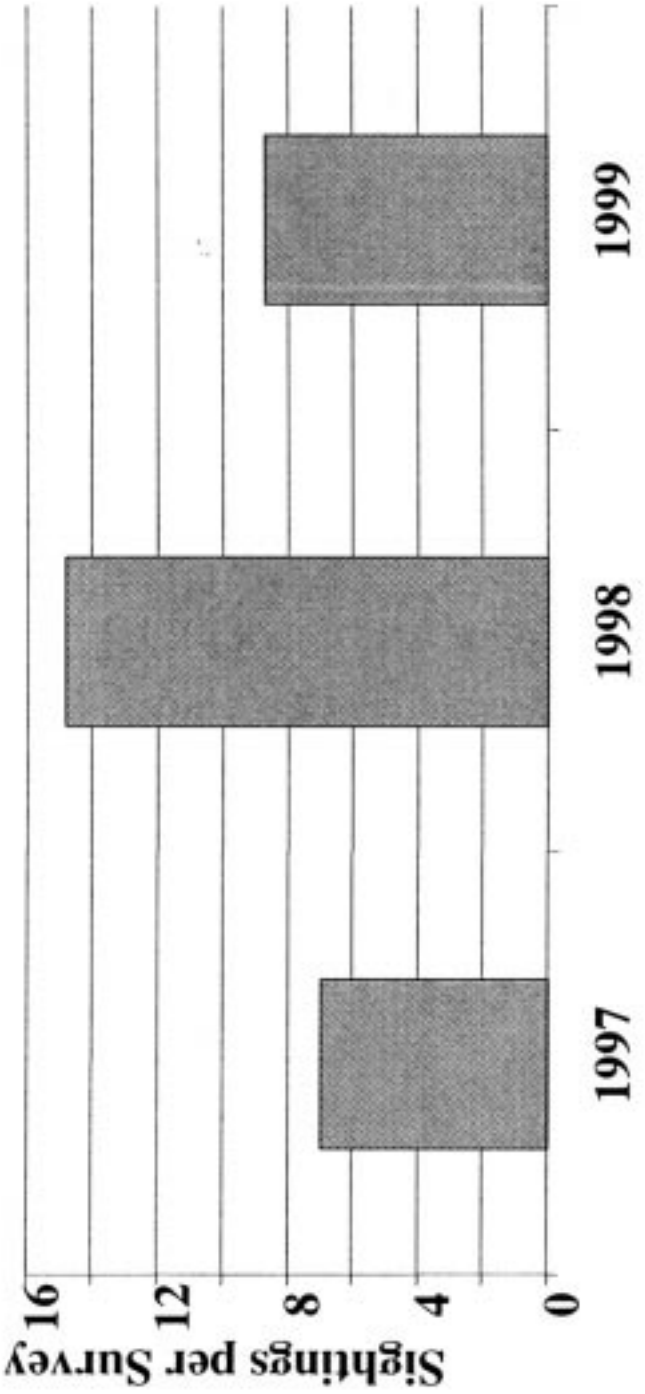

Figure 3: Blue and humpback whale sightings in Monterey Bay, California.